during a glow phase, applying an electrical voltage to a first lead layer, a second lead layer, a first electrode for detecting an ionic current, and a second electrode for detecting the ionic current.

30. (New) The method according to claim 29, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a same potential.

31. (New) The method according to claim 29, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a different potential --.

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 14 in the underlying PCT Application No. PCT/DE01/01472. This Preliminary Amendment adds new claims 15 to 31. The new claims, inter alia, conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(iii) and 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE01/01472 includes an International Search Report, dated October 15, 2001, a copy of which is included.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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[10191/2259]

SHEATHED-ELEMENT GLOW PLUG HAVING AN IONIC CURRENT SENSOR AND METHOD FOR OPERATING SUCH A SHEATHED-ELEMENT GLOW PLUG

[Background Information] FIELD OF THE INVENTION

The present invention [is based on] relates to a ceramic sheathed-element glow plug for a diesel [engines] engine having an ionic-current sensor [according to the species defined in the first independent claim. The German laid open print 34 28 371 has already described].

BACKGROUND INFORMATION

German Published Patent Application No. 34 28 371 describes a ceramic sheathed-element glow [plugs which have] plug that includes a ceramic heating element. The ceramic heating element bears an electrode made of a metallic material which is used to determine the electric conductivity of the ionized gas present in the combustion chamber of the internal combustion engine. In this case, the combustion chamber wall is used as the second electrode.

Furthermore, sheathed-element glow plugs are known which have a housing in which a rod-shaped heating element is disposed in a concentric bore hole. The heating element is made of at least one insulating layer, as well as a first and a second lead layer, the first and the second lead layers [being] connected via a bar at the tip of the heating element on the combustion chamber side. The insulating layer is made of electrically insulating ceramic material, and the first and second lead layers, as well as the bar, are made of electroconductive ceramic material.

[Summary of the Invention] SUMMARY OF THE INVENTION

The ceramic sheathed-element glow plug of the present invention with ionic-current sensor[, having the features of the first independent claim, has the] has an advantage that the sheathed-element glow plug with ionic-current sensor has a very simple design and is inexpensive to manufacture.

[The measures specified in the dependent claims permit advantageous further developments and improvements of the] It is possible to achieve a design of a sheathed-element glow plug [with ionic-current sensor indicated in the main claim. It is possible to achieve a particularly advantageous design of a sheathed-element glow plug] if the glow operation and the ionic-current measurement [can be] are carried out simultaneously. [It is also advantageous to lead the] The electrode for detecting ionic current may be led up to the end of the heating element on the combustion chamber side[, since the]. The ionic current may [thus] be detected in a region of the combustion chamber [which is significant for] where the combustion processes [taking] takes place in the combustion chamber. It is also [advantageous] illustrated to design two electrodes [for detecting] to detect ionic current in such a way that the ionic current flows from [the] one electrode to the other electrode, and thus only crosses a region of special interest for the ionic-current measurement. It is [likewise advantageous] shown to use the ceramic composite structure described below for the various heating-element layers, [whose] where conductivity and expansion [coefficient can] coefficients may be adapted very well. This [holds true equally] also applies for the precursor composites described below.

In the method for operating a sheathed-element glow plug having ionic-current measurement, [it is particularly advantageous to provide] the ionic-current detection may be provided during the glowing of the heating element, since it is of interest to detect the combustion process during the start phase of the internal combustion engine[, as well.].

[Further advantages come to light from the following description] BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a longitudinal sectional view of [the exemplary embodiments. Brief Description of the Drawing

Exemplary embodiments of the invention are shown in the drawings and are explained in greater detail in the following description.

Figure 1 shows schematically in a longitudinal section,] a sheathed-element glow plug of the present invention with ionic-current sensor[;].

Figure 2 [shows] is a schematic longitudinal [section] sectional view through the combustion-chamber-side end of a sheathed-element glow plug of the present invention with ionic-current sensor[;].

[Figures
3a and b each show a]Figure 3a shows a first schematic longitudinal [section] sectional view through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor[; and].

Figure [4] 3b shows a second schematic [cross-section] longitudinal sectional view through [a] the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

[Description of the Exemplary Embodiments] Figure 4 shows a schematic cross-sectional view through a heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

[Figure 1 shows] DETAILED DESCRIPTION

Figure 1 illustrates a sheathed-element glow plug of the present invention schematically in longitudinal section. A tubular[, preferably metallic housing 3] housing 3, which may be made of metallic material, contains a heating element 5 in its concentric bore hole at the end on the combustion chamber side. Heating element 5 [is] may be made of ceramic material. Heating

element 5 [has] may have a first lead layer 7 and a second lead layer 9, first lead layer 7 and second lead layer 9 [being] made of electroconductive ceramic material. At end 6 of heating element [3] 5 remote from the combustion chamber, first lead layer 7 and second lead layer 9 are connected by a bar 8 [likewise]. In the example embodiment illustrated, the bar 8 may be made of electroconductive ceramic material. First lead layer 7 and second lead layer 9 [are] may be separated from each other by an insulating layer 11. Insulating layer 11 [is] may be made of electrically insulating ceramic material. The interior of housing 3 is sealed in the direction of the combustion chamber by a combustion-chamber seal 13 surrounding heating element 5 in a ring shape. At the end of heating element 5 remote from the combustion chamber, first lead layer 7 is connected to a third connection 37. In the direction of the end of the sheathed-element glow plug remote from the combustion chamber, this third connection 37 is [in turn] connected to terminal stud 19. At its end remote from the combustion chamber, second lead layer 9 has a contact area 12 via which second lead layer 9 is electrically connected to housing 3 by way of electroconductive combustion-chamber seal 13. Housing 3 is connected to ground. In [one preferred exemplary] an example embodiment, contact area 12 may be constructed in such a way that in this region, the electrically insulating glass coating surrounding the end of heating element 5 remote from the combustion chamber is interrupted, and consequently an electrical contact is produced with combustion-chamber seal 13. In [one particularly preferred exemplary] another example embodiment, contact area 12 is provided with a metallic coating.

Terminal stud 19 is set apart from the end of heating element 5 remote from the combustion chamber by a ceramic spacer sleeve 27 disposed in the concentric bore hole of housing 3. In the direction of the end remote from the combustion chamber, terminal stud 19 is led through a clamping sleeve 29 and a metal sleeve 31. At the end of the sheathed-element glow plug remote from the combustion chamber, a circular connector 25, which effects the electrical connection, is mounted on terminal stud 19. The end of the

concentric bore hole of housing 3, remote from the combustion chamber, is sealed and electrically insulated by a tubing ring 21 and an insulating disk 23.

The present invention is [clarified more precisely once again with reference to] also illustrated in Figure 2. Only the end of a sheathed-element glow plug according to the present invention on the combustion chamber side is [shown] illustrated schematically in longitudinal section. Compared to Figure 1, heating element 5 is intersected in a plane transverse to the sectional plane of Figure 1. Here, only insulating layer 11 is visible. [Running within] Within insulating layer 11 [are] two electrodes 33 and 33' are placed for detecting ionic current which are broadened at end 6 of heating element 5 on the combustion chamber side. In a further [exemplary] example embodiment, electrodes 33 and 33' may also be applied outside on the insulating layer. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to a first connection 15. Second electrode 33' for detecting ionic current is likewise connected at the end of heating element 5 remote from the combustion chamber to a second connection 17. First connection 15 and second connection 17 are passed through terminal stud 19 to the end of the sheathed-element glow plug remote from the combustion chamber. As [already] previously mentioned, first lead layer 7 is connected to terminal stud 19 with the aid of a third connection 37.

The arrangement of the various layers of heating element 5 together with the associated connections are [shown] illustrated again with reference to Figure 3. Figure 3a [() shows] illustrates a heating element 5 in longitudinal section. First electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are disposed in insulating layer 11. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to first connection 15, and second electrode 33' for detecting ionic current is connected to second connection 17. In addition, at the end of heating element 5 on the combustion chamber

side, bar 8 is discernible which connects first lead layer 7 and second lead layer 9 to one another.

Figure 3b[)] shows heating element 5 which is intersected in a plane transverse to the plane in which heating element 5, which was [shown] illustrated in Figure 3a[)], is intersected. [Recognizable here are first] First lead layer 7 and second lead layer 9 [which] are interconnected via bar 8 at end 6 of heating element 5 remote from the combustion chamber. Third connection 37 is connected to first lead layer 7 at the end of heating element 5 remote from the combustion chamber.

[To better clarify the invention,] Figure 4 shows a cross-section through heating element 5 at the end remote from the combustion chamber. [It is discernible that first] First lead layer 7 is separated from second lead layer 9 by insulating layer 11. Arranged within insulating layer 11 is first connection 15 which is connected to first electrode 33 for detecting ionic current. Likewise arranged within insulating layer 11 is second connection 17 which is connected to second electrode 33' for detecting ionic current. [Furthermore, third] Third connection 37 is disposed within first lead layer 7. [It can be seen that, to] To better accommodate and insulate first and second electrodes 33, 33' for detecting ionic current, the insulating layer is broadened in the region in which these electrodes are arranged.

In a first [exemplary] example embodiment, the sheathed-element glow plug may be operated in such a way that during the start of the internal combustion engine, the sheathed-element glow plug is initially operated in heating mode. [This means that during] During the glow phase, a positive voltage with respect to ground is applied to third connection 37, so that a current flows across first lead layer 7, bar 8 and second lead layer 9. Due to the electrical resistance on this path, the temperature of the heating element rises, and the combustion chamber, into which the end of the sheathed-element glow plug on the combustion chamber side extends, is heated. After ending the glow phase, a voltage potential is applied to first

connection 15 and second connection 17, so that first electrode 33 and second electrode 33' are used as electrodes for measuring ionic current. If the combustion chamber is ionized due to the presence of ions, then an ionic current [can] may flow from electrodes 33, 33' for detecting ionic current to the combustion-chamber wall which is grounded. In this [exemplary] example embodiment, first electrode 33 for detecting ionic current and the second electrode for detecting ionic current act as electrodes at the same potential in parallel.

In a further [exemplary] example embodiment, [it is also possible to apply] a different voltage potential may be applied to first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current[,] so that an ionic current flows between first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current.

In another [exemplary] example embodiment, the glow operation and the detection of ionic current may be carried out simultaneously by the sheathed-element glow plug. [To that end, in each case the] The voltage [necessary] for the glow operation and for detecting ionic current is applied simultaneously to third connection 37 and to first and second connections 15, 17, respectively. [In this context, the] The voltage potentials may be selected such that first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are at the same or different potential, [that is to say,] as described above, the ionic current flows via the ionized combustion chamber to the combustion chamber wall, or from first electrode 33 for detecting ionic current via the ionized combustion chamber to second electrode 33' for detecting ionic current.

In a first [exemplary] example embodiment, the materials of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and electrode 33 for detecting ionic current, as well as second electrode 33' for detecting ionic current [should] may be made of ceramic material. This ensures that the thermal expansion coefficients of the materials scarcely differ, thus guaranteeing the

endurance strength of heating element 5. [In this context, the] The material of first lead layer 7, bar 8 and second lead layer 9 is selected such that the resistance of these layers is less than the resistance of insulating layer 11. [In the same way, the] The resistance of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current is less than the resistance of insulating layer 11.

In a further [exemplary] example embodiment, first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current may also be made of metallic material, e.g. platinum.

In [one preferred exemplary] another example embodiment, first lead layer 7, bar 8 and second lead layer 9, insulating layer 11 and possibly first electrode 33 and second electrode 33' are made of ceramic composite structures which contain at least two of the compounds AL_20_3, $MoSi_2$, Si_3N_4 and Y_20_3. These composite structures are obtainable by a one-step or multi-step sintering process. The specific resistance of the layers may preferably be determined by the $MoSi_2$ content and/or the grain size of $MoSi_2$; the $MoSi_2$ content of first lead layer 7, of bar 8 and of second lead layer 9, as well as of first and second electrodes 33, 33' for detecting ionic current [is preferably] may be higher than the $MoSi_2$ content of insulating layer 11.

In a further [exemplary] example embodiment, first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are made of a composite precursor ceramic having different portions of fillers. The matrix of this material is made of polysiloxanes, polysesquioxanes, polysilanes or polysilazanes which may be doped with boron, nitrogen or aluminum and are produced by pyrolysis. At least one of the compounds $A1_20_3$, $MoSi_2$, $Si0_2$ and SiC forms the filler for the individual layers. Analogous to the composite structure indicated above, the $MoSi_2$ content and/or the grain size of $MoSi_2$ may [preferably] determine the resistance of the layers. The $MoSi_2$ content of first lead layer 7, of bar 8 and of second lead layer 9, and possibly of first and

second electrodes 33, 33' for detecting ionic current [is preferably] may be set higher than the $MoSi_2$ content of insulating layer 11. In the [exemplary] example embodiments indicated above, the compositions of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are selected such that their thermal expansion coefficients and the shrinkages occurring during the sintering and pyrolysis processes are identical, so that no cracks develop in heating element 5.

[What is claimed is:

1. A sheathed-element glow plug with ionic-current sensor, comprising a housing (3) and a rod-shaped heating element (5) arranged in a concentric bore hole of the housing, the heating element (5) having at least one insulating layer (11) as well as a first lead layer (7) and a second lead layer (9), the first lead layer (7) and the second lead layer (9) being connected via a bar (8) at end (6) of the heating element (5) on the combustion chamber side, the first and second lead layers (7, 9) and the bar (8) being made of electroconductive ceramic material, and the insulating layer (11) being made of electrically insulating ceramic material,wherein the heating element (5) has a first electrode (33) for detecting ionic current and a second electrode (33') for detecting ionic current which are embedded in the insulating layer (11) or are applied on the insulating layer (11).

2. The sheathed-element glow plug as recited in Claim 1,wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of metallic material, preferably platinum.

3. The sheathed-element glow plug as recited in Claim 1,wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of electroconductive ceramic material.

4. The sheathed-element glow plug as recited in Claim 1,wherein a first electrical connection (15) and a second electrical connection (17) are provided at the end of the heating element (6) remote from the combustion chamber, the first electrical connection (15) being connected to the end, remote from the combustion chamber, of the first electrode (33) for detecting ionic current, and the second electrical connection (17) being connected to the end, remote from the combustion chamber, of the second electrode (33') for detecting ionic current.

5. The sheathed-element glow plug as recited in Claim 1,wherein the second lead layer (9) is connected to ground via the housing (3) and combustion-chamber seal (13).

6. The sheathed-element glow plug as recited in Claim 1,wherein at the end of the heating element (6)remote from the combustion chamber, a tubular spacer sleeve (27) made of electrically insulating material is arranged within the concentric bore hole of the housing (3).

7. The sheathed-element glow plug as recited in Claim 1,wherein the insulating layer (11), the first lead layer (7), the bar (8) and the second lead layer (9) are made of ceramic composite structures which are obtainable from at least two of the compounds A1203, MoSi2, Si3N4 and Y203 using a one-step or multi-step sintering process.

8. The sheathed-element glow plug as recited in Claim 1,wherein the insulating layer (11), the first lead layer (7), the bar (8) and the second lead layer (9) are made of a composite precursor ceramic, the matrix material including polysiloxanes, polysilsesquioxanes, polysilanes or polysilazanes which may be doped with boron, nitrogen or aluminum and which were produced by pyrolysis, the filler being formed from at least one of the compounds A1203, MoSi2, Si02 and SiC.

9. The sheathed-element glow plug as recited in Claim 3,wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of ceramic composite structures which are obtainable from at least two of the compounds A1203, MoSi2, Si3N4 and Y203 using a one-step or multi-step sintering process.

10. The sheathed-element glow plug as recited in Claim 3,wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of a composite precursor ceramic, the matrix material including polysiloxanes, polysilsesquioxanes, polysilanes or

polysilazanes which may be doped with boron, nitrogen or aluminum and which were produced by pyrolysis, the filler being formed from at least one of the compounds A1203, MoSi2, Si02 and SiC.

11. A method for operating a sheathed-element glow plug having an ionic-current sensor as recited in Claim 1,
wherein during a glow phase, an electrical voltage is applied merely to the first and the second lead layers (7, 9), and after ending the glow phase, an electrical voltage is applied merely to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

12. A method for operating a sheathed-element glow plug having an ionic-current sensor as recited in Claim 1,
wherein during the glow phase, an electrical voltage is applied both to the first and the second lead layers (7, 9), as well as to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

13. The method as recited in one of Claims 11 or 12,
wherein a voltage having the same potential is applied to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

14. The method as recited in one of Claims 11 or 12,
wherein a voltage having different potential is applied to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

Abstract] ABSTRACT

A sheathed-element glow plug having an ionic-current sensor, as well as a method for operating a sheathed-element glow plug having an ionic-current sensor are described, the sheathed-element glow plug having a housing [(3)] and a rod-shaped heating element [(5)] arranged in a concentric bore hole of the housing. The heating element [(5)] has at least one insulating layer [(11)] as well as a first lead layer [(7)] and a second lead layer[(9)], the first lead layer [(7)] and the second lead layer [(9)] being connected via a bar [(8)] at the end [(6)] of the heating element [(5)] on the combustion chamber side, the first and second lead layers [(7, 9)] and the bar [(8)] being made of electroconductive ceramic material, and the insulating layer [(11)] being made of electrically insulating ceramic material. The heating element [(5)] has a first electrode [(33)] for detecting ionic current and a second electrode [(33')] for detecting ionic current which are embedded in the insulating layer [(11)] or [are] applied on the insulating layer[(11)].